

# Aluminum Capacitors

## SMD (Chip), High Temperature, Low Impedance



Fig. 1

| QUICK REFERENCE DATA                                 |                                 |
|------------------------------------------------------|---------------------------------|
| DESCRIPTION                                          | VALUE                           |
| Nominal case sizes<br>(L x W x H in mm)              | 10 x 10 x 10<br>to 18 x 18 x 21 |
| Rated capacitance range, C <sub>R</sub>              | 22 µF to 4700 µF                |
| Tolerance on C <sub>R</sub>                          | ± 20 %                          |
| Rated voltage range, U <sub>R</sub>                  | 16 V to 63 V                    |
| Category temperature range                           | - 55 °C to + 125 °C             |
| Endurance test at 125 °C                             | 1000 h to 5000 h                |
| Useful life at 125 °C                                | 1500 h to 6000 h                |
| Useful life at 40 °C<br>1.8 x I <sub>R</sub> applied | 150 000 h to 400 000 h          |
| Shelf life at 0 V, 125 °C                            | 1000 h                          |
| Based on sectional<br>specification                  | IEC 60384-18/CECC 32300         |
| Climatic category IEC 60068                          | 55/125/56                       |

### FEATURES

- Polarized aluminum electrolytic capacitors, non-solid electrolyte, self healing
- SMD-version with base plate, lead (Pb)-free reflow solderable
- Charge and discharge proof, no peak current limitation
- High temperature reflow soldering according to JEDEC J-STD-020
- Vibration proof, 4-pin version and 6-pin version
- AEC-Q200 qualified
- Material categorization: For definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



### APPLICATIONS

- SMD technology, for high temperature reflow soldering
- Industrial and professional applications
- Automotive, general industrial, telecom
- Smoothing, filtering, buffering

### MARKING

- Rated capacitance (in µF)
- Rated voltage (in V)
- Date code, in accordance with IEC 60062
- Black mark or “-” sign indicating the cathode (the anode is identified by bevelled edges)
- Code indicating group number (T)

### PACKAGING

Supplied in blister tape on reel

**SELECTION CHART FOR  $C_R$ ,  $U_R$ , AND RELEVANT NOMINAL CASE SIZES (L x W x H in mm)**

| $C_R$<br>( $\mu F$ ) | $U_R$ (V)        |                  |                  |                  |                  |
|----------------------|------------------|------------------|------------------|------------------|------------------|
|                      | 16               | 25               | 35               | 50               | 63               |
| 22                   | →                | →                | →                | →                | 10 x 10 x 10     |
| 33                   | →                | →                | →                | →                | 10 x 10 x 10     |
| 47                   | →                | →                | 10 x 10 x 10     | 10 x 10 x 10     | 10 x 10 x 10     |
| 68                   | →                | →                | →                | 10 x 10 x 10     | 10 x 10 x 10     |
| 100                  | →                | →                | 10 x 10 x 10     | 10 x 10 x 10     | 10 x 10 x 12     |
|                      |                  |                  |                  | 10 x 10 x 12     | 12.5 x 12.5 x 13 |
| 150                  | →                | →                | 10 x 10 x 10     | 10 x 10 x 12     | 12.5 x 12.5 x 13 |
| 220                  | →                | 10 x 10 x 10     | 10 x 10 x 12     | 12.5 x 12.5 x 13 | 12.5 x 12.5 x 16 |
| 330                  | 10 x 10 x 10     | 10 x 10 x 12     | 12.5 x 12.5 x 13 | 12.5 x 12.5 x 16 | 16 x 16 x 16     |
| 470                  | 10 x 10 x 12     | 12.5 x 12.5 x 13 | 12.5 x 12.5 x 16 | 16 x 16 x 16     | 16 x 16 x 16     |
| 680                  | 12.5 x 12.5 x 13 | 12.5 x 12.5 x 16 | 16 x 16 x 16     | 16 x 16 x 16     | 18 x 18 x 16     |
| 820                  | →                | →                | →                | →                | 16 x 16 x 21     |
| 1000                 | 12.5 x 12.5 x 16 | 16 x 16 x 16     | 16 x 16 x 16     | 16 x 16 x 21     | 18 x 18 x 21     |
|                      |                  |                  |                  | 18 x 18 x 16     |                  |
| 1200                 | →                | →                | 18 x 18 x 16     | 18 x 18 x 21     | -                |
| 1500                 | 16 x 16 x 16     | 16 x 16 x 16     | 16 x 16 x 21     | -                | -                |
| 1800                 | →                | →                | 18 x 18 x 21     | -                | -                |
| 2200                 | 16 x 16 x 16     | 16 x 16 x 21     | -                | -                | -                |
|                      |                  | 18 x 18 x 16     | -                | -                | -                |
| 2700                 | →                | 18 x 18 x 21     | -                | -                | -                |
| 3300                 | 16 x 16 x 21     | -                | -                | -                | -                |
|                      | 18 x 18 x 16     | -                | -                | -                | -                |
| 3900                 | 18 x 18 x 21     | -                | -                | -                | -                |
| 4700                 | 18 x 18 x 21     | -                | -                | -                | -                |

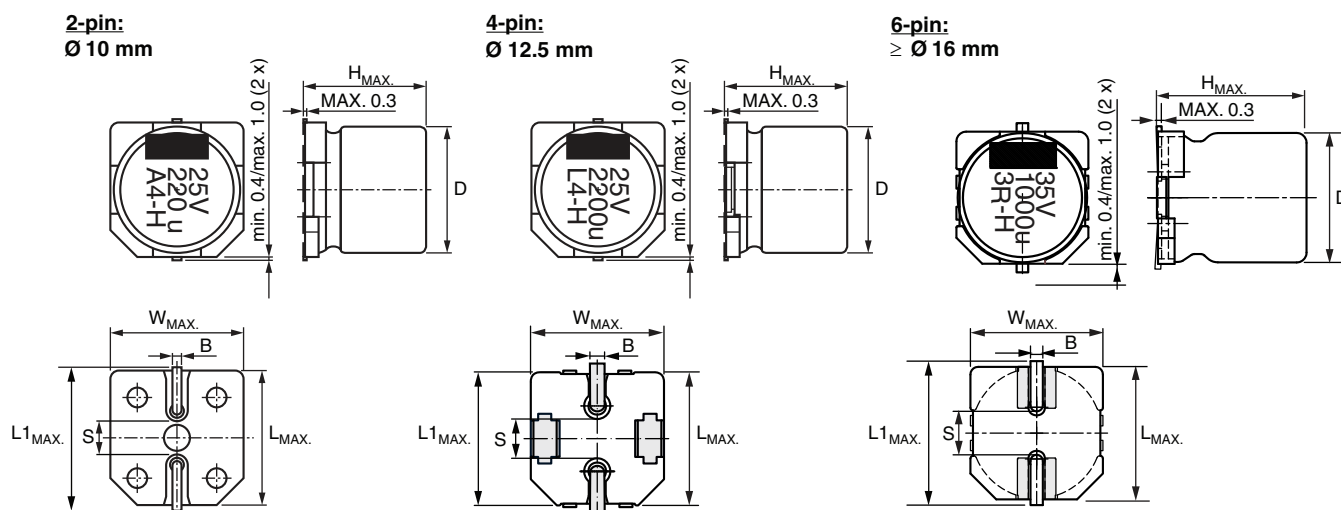


Fig. 2 - Dimensional outline



Table 1

| <b>DIMENSIONS in millimeters AND MASS</b> |              |                   |                   |                   |      |                   |     |                    |             |
|-------------------------------------------|--------------|-------------------|-------------------|-------------------|------|-------------------|-----|--------------------|-------------|
| NOMINAL<br>CASE SIZE<br>L x W x H         | CASE<br>CODE | L <sub>MAX.</sub> | W <sub>MAX.</sub> | H <sub>MAX.</sub> | Ø D  | B <sub>MAX.</sub> | S   | L1 <sub>MAX.</sub> | MASS<br>(g) |
| 10 x 10 x 10                              | 1010         | 10.5              | 10.5              | 10.5              | 10.0 | 1.0               | 3.5 | 12.1               | ≈ 1.3       |
| 10 x 10 x 12                              | 1012         | 10.5              | 10.5              | 12.5              | 10.0 | 1.0               | 3.5 | 12.1               | ≈ 1.5       |
| 12.5 x 12.5 x 13                          | 1213         | 12.9              | 12.9              | 14.0              | 12.5 | 1.3               | 3.6 | 14.9               | ≈ 2.6       |
| 12.5 x 12.5 x 16                          | 1216         | 12.9              | 12.9              | 16.5              | 12.5 | 1.3               | 3.6 | 14.9               | ≈ 2.8       |
| 16 x 16 x 16                              | 1616         | 16.6              | 16.6              | 17.5              | 16.0 | 1.3               | 6.5 | 18.6               | ≈ 5.5       |
| 16 x 16 x 21                              | 1621         | 16.6              | 16.6              | 22.0              | 16.0 | 1.3               | 6.5 | 18.6               | ≈ 6.0       |
| 18 x 18 x 16                              | 1816         | 19.0              | 19.0              | 17.5              | 18.0 | 1.3               | 6.5 | 21.0               | ≈ 8.0       |
| 18 x 18 x 21                              | 1821         | 19.0              | 19.0              | 22.0              | 18.0 | 1.3               | 6.5 | 21.0               | ≈ 8.3       |

Table 2

| <b>TAPE AND REEL DIMENSIONS in millimeters, PACKAGING QUANTITIES</b> |              |                         |                 |                                     |               |                                   |
|----------------------------------------------------------------------|--------------|-------------------------|-----------------|-------------------------------------|---------------|-----------------------------------|
| NOMINAL<br>CASE SIZE<br>L x W x H                                    | CASE<br>CODE | PITCH<br>P <sub>1</sub> | TAPE WIDTH<br>W | TAPE<br>THICKNESS<br>T <sub>2</sub> | REEL DIAMETER | PACKAGING<br>QUANTITY<br>PER REEL |
| 10 x 10 x 10                                                         | 1010         | 16                      | 24              | 11.6                                | 380           | 500                               |
| 10 x 10 x 12                                                         | 1012         | 16                      | 24              | 12.8                                | 330           | 250                               |
| 12.5 x 12.5 x 13                                                     | 1213         | 20                      | 24              | 16.2                                | 380           | 250                               |
| 12.5 x 12.5 x 16                                                     | 1216         | 24                      | 32              | 18.5                                | 380           | 200                               |
| 16 x 16 x 16                                                         | 1616         | 28                      | 44              | 18.9                                | 380           | 150                               |
| 16 x 16 x 21                                                         | 1621         | 28                      | 44              | 23.4                                | 380           | 100                               |
| 18 x 18 x 16                                                         | 1816         | 32                      | 44              | 18.9                                | 380           | 125                               |
| 18 x 18 x 21                                                         | 1821         | 32                      | 44              | 23.4                                | 380           | 100                               |

**Note**

- Detailed tape dimensions see section "PACKAGING"

## MOUNTING

The capacitors are designed for automatic placement on to printed-circuit boards.

Optimum dimensions of soldering pads depend amongst others on soldering method, mounting accuracy, print layout and/or adjacent components.

For recommended soldering pad dimensions, refer to Fig. 3 and Table 3.

## SOLDERING

Soldering conditions are defined by the curve, temperature versus time, where the temperature is that measured on the component during processing.

For maximum conditions refer to Fig. 4.

Any temperature versus time curve which does not exceed the specified maximum curves may be applied.

As a general principle, temperature and duration shall be the **minimum** necessary required to ensure good soldering connections. However, the specified maximum curves should never be exceeded.



Fig. 3 - Recommended soldering pad dimensions

Table 3

| RECOMMENDED SOLDERING PAD DIMENSIONS in millimeters |     |     |     |     |     |     |
|-----------------------------------------------------|-----|-----|-----|-----|-----|-----|
| CASE CODE                                           | a   | b   | c   | d   | e   | f   |
| 1010                                                | 4.4 | 2.5 | 4.0 | -   | -   | -   |
| 1012                                                | 4.4 | 2.5 | 4.0 | -   | -   | -   |
| 1213                                                | 6.3 | 2.5 | 4.0 | 4.2 | 5.0 | 5.6 |
| 1216                                                | 6.3 | 2.5 | 4.0 | 4.2 | 5.0 | 5.6 |
| 1616                                                | 7.8 | 9.6 | 4.7 | -   | -   | -   |
| 1621                                                | 7.8 | 9.6 | 4.7 | -   | -   | -   |
| 1816                                                | 8.8 | 9.6 | 4.7 | -   | -   | -   |
| 1821                                                | 8.8 | 9.6 | 4.7 | -   | -   | -   |

# **ADVANCED SOLDERING PROFILE FOR LEAD (Pb)-FREE REFLOW PROCESS ACCORDING TO JEDEC J-STD-020**

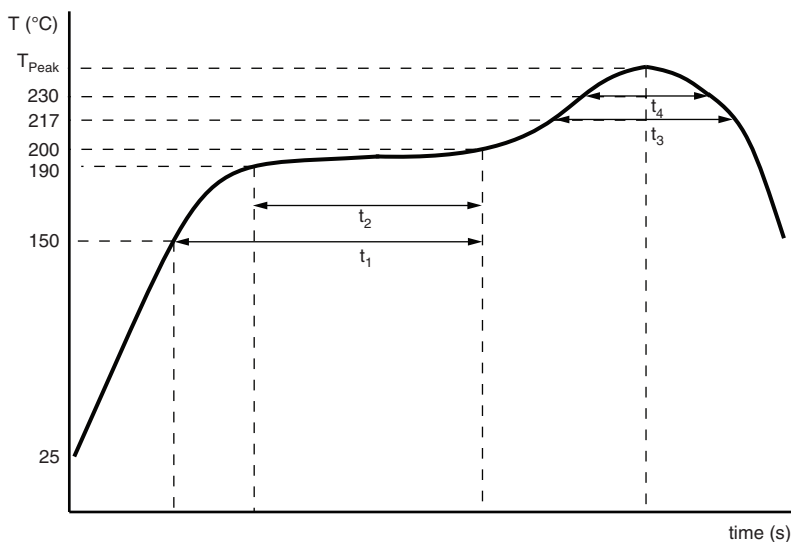


Fig. 4 - Maximum temperature load during reflow soldering

Table 4

| REFLOW SOLDERING CONDITIONS for MAL214699xxxE3    |                           |                           |                           |
|---------------------------------------------------|---------------------------|---------------------------|---------------------------|
| PROFILE FEATURES                                  | CASE CODE<br>1010 TO 1012 | CASE CODE<br>1213 TO 1216 | CASE CODE<br>1616 TO 1821 |
| Max. time from 25 °C to $T_{Peak}$                | 300 s                     | 300 s                     | 300 s                     |
| Min. ramp-up rate to 150 °C                       | 3 K/s                     | 3 K/s                     | 3 K/s                     |
| Max. time from 150 °C to 200 °C ( $t_1$ )         | 150 s                     | 150 s                     | 150 s                     |
| Max. time from 190 °C to 200 °C ( $t_2$ )         | 110 s                     | 110 s                     | 110 s                     |
| Ramp up rate from 200 °C to $T_{Peak}$            | 0.5 K/s to 3 K/s          | 0.5 K/s to 3 K/s          | 0.5 K/s to 3 K/s          |
| Max. time above $T_{Liquidus}$ (217 °C) ( $t_3$ ) | 90 s                      | 90 s                      | 90 s                      |
| Max. time above 230 °C ( $t_4$ )                  | 70 s                      | 65 s                      | 60 s                      |
| Peak temperature $T_{Peak}$                       | 260 °C                    | 250 °C                    | 245 °C                    |
| Max. time above $T_{Peak}$ minus 5 °C             | 40 s                      | 30 s                      | 30 s                      |
| Ramp-down rate from $T_{Liquidus}$                | 3 K/s to 6 K/s            | 3 K/s to 6 K/s            | 3 K/s to 6 K/s            |

## **Notes**

- Temperature measuring point on top of the case and on terminals.
- Max. 2 runs with pause of min. 30 min in between.

| ELECTRICAL DATA |                                                   |
|-----------------|---------------------------------------------------|
| SYMBOL          | DESCRIPTION                                       |
| $C_R$           | Rated capacitance at 100 Hz, tolerance $\pm 20\%$ |
| $I_R$           | Rated RMS ripple current at 100 kHz, 125 °C       |
| $I_{L2}$        | Max. leakage current after 2 min at $U_R$         |
| $\tan \delta$   | Max. dissipation factor at 100 Hz                 |
| $Z$             | Max. impedance at 100 kHz                         |

**Note**

- Unless otherwise specified, all electrical values in Table 5 apply at  $T_{amb} = 20\text{ °C}$ ,  $P = 86\text{ kPa}$  to  $106\text{ kPa}$ ,  $RH = 45\%$  to  $75\%$

**ORDERING EXAMPLE**

Electrolytic capacitor 146 CTI series

220  $\mu\text{F}/50\text{ V}$ ;  $\pm 20\%$ 

Nominal case size: 12.5 mm x 12.5 mm x 13 mm; taped on reel

Ordering code: MAL214699106E3

**Table 5**

| ELECTRICAL DATA AND ORDERING INFORMATION |                            |                                           |                                    |                                        |                         |                                         |                                           |                                |
|------------------------------------------|----------------------------|-------------------------------------------|------------------------------------|----------------------------------------|-------------------------|-----------------------------------------|-------------------------------------------|--------------------------------|
| $U_R$<br>(V)                             | $C_R$<br>( $\mu\text{F}$ ) | NOMINAL<br>CASE SIZE<br>L x W x H<br>(mm) | $I_R$<br>125 °C<br>100 kHz<br>(mA) | $I_{L2}$<br>2 min<br>( $\mu\text{A}$ ) | $\tan \delta$<br>100 Hz | $Z$<br>100 kHz<br>20 °C<br>( $\Omega$ ) | $Z$<br>100 kHz<br>- 40 °C<br>( $\Omega$ ) | ORDERING<br>CODE<br>MAL2146... |
| 16                                       | 330                        | 10 x 10 x 10                              | 750                                | 53                                     | 0.16                    | 0.150                                   | 1.35                                      | 99501E3                        |
|                                          | 470                        | 10 x 10 x 12                              | 900                                | 75                                     | 0.16                    | 0.097                                   | 0.87                                      | 99502E3                        |
|                                          | 680                        | 12.5 x 12.5 x 13                          | 1100                               | 109                                    | 0.16                    | 0.075                                   | 0.68                                      | 99503E3                        |
|                                          | 1000                       | 12.5 x 12.5 x 16                          | 1300                               | 160                                    | 0.16                    | 0.058                                   | 0.52                                      | 99504E3                        |
|                                          | 1500                       | 16 x 16 x 16                              | 1400                               | 240                                    | 0.16                    | 0.050                                   | 0.45                                      | 99505E3                        |
|                                          | 2200                       | 16 x 16 x 16                              | 1400                               | 352                                    | 0.18                    | 0.050                                   | 0.45                                      | 99506E3                        |
|                                          | 3300                       | 16 x 16 x 21                              | 1660                               | 528                                    | 0.20                    | 0.035                                   | 0.32                                      | 99507E3                        |
|                                          | 3300                       | 18 x 18 x 16                              | 1500                               | 528                                    | 0.20                    | 0.050                                   | 0.45                                      | 99508E3                        |
|                                          | 3900                       | 18 x 18 x 21                              | 1750                               | 624                                    | 0.20                    | 0.035                                   | 0.32                                      | 99509E3                        |
|                                          | 4700                       | 18 x 18 x 21                              | 1750                               | 752                                    | 0.22                    | 0.035                                   | 0.32                                      | 99511E3                        |
| 25                                       | 220                        | 10 x 10 x 10                              | 750                                | 55                                     | 0.14                    | 0.150                                   | 1.35                                      | 99601E3                        |
|                                          | 330                        | 10 x 10 x 12                              | 900                                | 83                                     | 0.14                    | 0.097                                   | 0.87                                      | 99602E3                        |
|                                          | 470                        | 12.5 x 12.5 x 13                          | 1100                               | 118                                    | 0.14                    | 0.075                                   | 0.68                                      | 99603E3                        |
|                                          | 680                        | 12.5 x 12.5 x 16                          | 1300                               | 170                                    | 0.14                    | 0.058                                   | 0.52                                      | 99604E3                        |
|                                          | 1000                       | 16 x 16 x 16                              | 1400                               | 250                                    | 0.14                    | 0.050                                   | 0.45                                      | 99605E3                        |
|                                          | 1500                       | 16 x 16 x 16                              | 1400                               | 375                                    | 0.14                    | 0.050                                   | 0.45                                      | 99606E3                        |
|                                          | 2200                       | 16 x 16 x 21                              | 1660                               | 550                                    | 0.16                    | 0.035                                   | 0.32                                      | 99607E3                        |
|                                          | 2200                       | 18 x 18 x 16                              | 1500                               | 550                                    | 0.16                    | 0.050                                   | 0.45                                      | 99608E3                        |
|                                          | 2700                       | 18 x 18 x 21                              | 1750                               | 675                                    | 0.16                    | 0.035                                   | 0.32                                      | 99609E3                        |
|                                          |                            |                                           |                                    |                                        |                         |                                         |                                           |                                |
| 35                                       | 47                         | 10 x 10 x 10                              | 750                                | 17                                     | 0.12                    | 0.150                                   | 1.35                                      | 99001E3                        |
|                                          | 100                        | 10 x 10 x 10                              | 750                                | 35                                     | 0.12                    | 0.150                                   | 1.35                                      | 99002E3                        |
|                                          | 150                        | 10 x 10 x 10                              | 750                                | 53                                     | 0.12                    | 0.150                                   | 1.35                                      | 99003E3                        |
|                                          | 220                        | 10 x 10 x 12                              | 900                                | 77                                     | 0.12                    | 0.097                                   | 0.87                                      | 99004E3                        |
|                                          | 330                        | 12.5 x 12.5 x 13                          | 1100                               | 116                                    | 0.12                    | 0.075                                   | 0.68                                      | 99005E3                        |
|                                          | 470                        | 12.5 x 12.5 x 16                          | 1300                               | 165                                    | 0.12                    | 0.058                                   | 0.52                                      | 99006E3                        |
|                                          | 680                        | 16 x 16 x 16                              | 1400                               | 238                                    | 0.12                    | 0.050                                   | 0.45                                      | 99007E3                        |
|                                          | 1000                       | 16 x 16 x 16                              | 1400                               | 350                                    | 0.12                    | 0.050                                   | 0.45                                      | 99008E3                        |
|                                          | 1200                       | 18 x 18 x 16                              | 1500                               | 420                                    | 0.12                    | 0.050                                   | 0.45                                      | 99009E3                        |
|                                          | 1500                       | 16 x 16 x 21                              | 1660                               | 525                                    | 0.12                    | 0.035                                   | 0.32                                      | 99011E3                        |
|                                          | 1800                       | 18 x 18 x 21                              | 1750                               | 630                                    | 0.12                    | 0.035                                   | 0.32                                      | 99012E3                        |
|                                          |                            |                                           |                                    |                                        |                         |                                         |                                           |                                |
|                                          |                            |                                           |                                    |                                        |                         |                                         |                                           |                                |

| ELECTRICAL DATA AND ORDERING INFORMATION |                     |                                           |                                    |                                 |                         |                                       |                                         |                                |
|------------------------------------------|---------------------|-------------------------------------------|------------------------------------|---------------------------------|-------------------------|---------------------------------------|-----------------------------------------|--------------------------------|
| $U_R$<br>(V)                             | $C_R$<br>( $\mu$ F) | NOMINAL<br>CASE SIZE<br>L x W x H<br>(mm) | $I_R$<br>125 °C<br>100 kHz<br>(mA) | $I_{L2}$<br>2 min<br>( $\mu$ A) | $\tan \delta$<br>100 Hz | Z<br>100 kHz<br>20 °C<br>( $\Omega$ ) | Z<br>100 kHz<br>- 40 °C<br>( $\Omega$ ) | ORDERING<br>CODE<br>MAL2146... |
| 50                                       | 47                  | 10 x 10 x 10                              | 600                                | 24                              | 0.10                    | 0.240                                 | 2.16                                    | 99101E3                        |
|                                          | 68                  | 10 x 10 x 10                              | 600                                | 34                              | 0.10                    | 0.240                                 | 2.16                                    | 99102E3                        |
|                                          | 100                 | 10 x 10 x 10                              | 600                                | 50                              | 0.10                    | 0.240                                 | 2.16                                    | 99103E3                        |
|                                          | 100                 | 10 x 10 x 12                              | 700                                | 50                              | 0.10                    | 0.170                                 | 1.53                                    | 99104E3                        |
|                                          | 150                 | 10 x 10 x 12                              | 700                                | 75                              | 0.10                    | 0.170                                 | 1.53                                    | 99105E3                        |
|                                          | 220                 | 12.5 x 12.5 x 13                          | 900                                | 110                             | 0.10                    | 0.120                                 | 1.08                                    | 99106E3                        |
|                                          | 330                 | 12.5 x 12.5 x 16                          | 1100                               | 165                             | 0.10                    | 0.085                                 | 0.76                                    | 99107E3                        |
|                                          | 470                 | 16 x 16 x 16                              | 1300                               | 235                             | 0.10                    | 0.072                                 | 0.65                                    | 99108E3                        |
|                                          | 680                 | 16 x 16 x 16                              | 1300                               | 340                             | 0.10                    | 0.072                                 | 0.65                                    | 99109E3                        |
|                                          | 1000                | 16 x 16 x 21                              | 1500                               | 500                             | 0.10                    | 0.052                                 | 0.47                                    | 99111E3                        |
|                                          | 1000                | 18 x 18 x 16                              | 1300                               | 500                             | 0.10                    | 0.070                                 | 0.63                                    | 99112E3                        |
|                                          | 1200                | 18 x 18 x 21                              | 1600                               | 600                             | 0.10                    | 0.049                                 | 0.44                                    | 99113E3                        |
| 63                                       | 22                  | 10 x 10 x 10                              | 400                                | 14                              | 0.10                    | 0.430                                 | 3.90                                    | 99801E3                        |
|                                          | 33                  | 10 x 10 x 10                              | 470                                | 21                              | 0.10                    | 0.380                                 | 3.40                                    | 99802E3                        |
|                                          | 47                  | 10 x 10 x 10                              | 470                                | 30                              | 0.10                    | 0.380                                 | 3.40                                    | 99803E3                        |
|                                          | 68                  | 10 x 10 x 10                              | 470                                | 43                              | 0.10                    | 0.380                                 | 3.40                                    | 99804E3                        |
|                                          | 100                 | 10 x 10 x 12                              | 550                                | 63                              | 0.10                    | 0.290                                 | 2.61                                    | 99805E3                        |
|                                          | 100                 | 12.5 x 12.5 x 13                          | 650                                | 63                              | 0.10                    | 0.210                                 | 1.89                                    | 99806E3                        |
|                                          | 150                 | 12.5 x 12.5 x 13                          | 650                                | 95                              | 0.10                    | 0.210                                 | 1.89                                    | 99807E3                        |
|                                          | 220                 | 12.5 x 12.5 x 16                          | 800                                | 139                             | 0.10                    | 0.160                                 | 1.44                                    | 99808E3                        |
|                                          | 330                 | 16 x 16 x 16                              | 1050                               | 208                             | 0.10                    | 0.100                                 | 0.90                                    | 99809E3                        |
|                                          | 470                 | 16 x 16 x 16                              | 1050                               | 296                             | 0.10                    | 0.100                                 | 0.90                                    | 99811E3                        |
|                                          | 680                 | 18 x 18 x 16                              | 1150                               | 428                             | 0.10                    | 0.095                                 | 0.86                                    | 99812E3                        |
|                                          | 820                 | 16 x 16 x 21                              | 1300                               | 517                             | 0.10                    | 0.075                                 | 0.68                                    | 99813E3                        |
|                                          | 1000                | 18 x 18 x 21                              | 1400                               | 630                             | 0.10                    | 0.072                                 | 0.65                                    | 99814E3                        |

Table 6

| ADDITIONAL ELECTRICAL DATA                   |                                                             |                                          |
|----------------------------------------------|-------------------------------------------------------------|------------------------------------------|
| PARAMETER                                    | CONDITIONS                                                  | VALUE                                    |
| <b>Voltage</b>                               |                                                             |                                          |
| Surge voltage for short periods              | IEC 60384-18, subclause 4.14                                | $U_s \leq 1.15 \times U_R$               |
| Reverse voltage for short periods            | IEC 60384-18, subclause 4.16; $T_A \leq 105$ °C             | $U_{rev} \leq 1$ V                       |
| <b>Current</b>                               |                                                             |                                          |
| Leakage current                              | After 2 min at $U_R$                                        | $I_{L2} \leq 0.01 \times C_R \times U_R$ |
| <b>Inductance</b>                            |                                                             |                                          |
| Equivalent series inductance (ESL)           | $\varnothing D = 10$ mm                                     | Typ. 8 nH                                |
|                                              | $\varnothing D \geq 12.5$ mm                                | Typ. 11 nH                               |
| <b>Resistance</b>                            |                                                             |                                          |
| Equivalent series resistance (ESR) at 100 Hz | Calculated from $\tan \delta_{max}$ and $C_R$ (see Table 5) | $ESR = \tan \delta / 2\pi f C_R$         |

### CAPACITANCE (C)



Fig. 5 - Typical multiplier of capacitance as a function of ambient temperature

### DISSIPATION FACTOR ( $\tan \delta$ )



Fig. 6 - Typical multiplier of dissipation factor ( $\tan \delta$ ) as a function of ambient temperature

### EQUIVALENT SERIES RESISTANCE (ESR)



Fig. 7 - Typical multiplier of ESR as a function of frequency

### IMPEDANCE (Z)



Fig. 8 - Typical impedance as a function of frequency



Fig. 9 - Typical impedance as a function of frequency

## RIPPLE CURRENT AND USEFUL LIFE

Table 7

| ENDURANCE TEST DURATION AND USEFUL LIFE AS A FUNCTION OF CASE SIZE |           |                               |                                 |                                                             |
|--------------------------------------------------------------------|-----------|-------------------------------|---------------------------------|-------------------------------------------------------------|
| NOMINAL CASE SIZE<br>Ø D x L<br>(mm)                               | CASE CODE | ENDURANCE<br>AT 125 °C<br>(h) | USEFUL LIFE<br>AT 125 °C<br>(h) | USEFUL LIFE AT 40 °C<br>1.8 x I <sub>R</sub> APPLIED<br>(h) |
| 10 x 10 x 10                                                       | 1010      | 1000                          | 1500                            | 150 000                                                     |
| 10 x 10 x 12                                                       | 1012      | 1500                          | 2000                            | 200 000                                                     |
| 12.5 x 12.5 x 13                                                   | 1213      | 2500                          | 3000                            | 300 000                                                     |
| 12.5 x 12.5 x 16                                                   | 1216      | 3000                          | 4000                            | 325 000                                                     |
| 16 x 16 x 16                                                       | 1616      | 4000                          | 5000                            | 350 000                                                     |
| 16 x 16 x 21                                                       | 1621      | 5000                          | 6000                            | 400 000                                                     |
| 18 x 18 x 16                                                       | 1816      | 4000                          | 5000                            | 350 000                                                     |
| 18 x 18 x 21                                                       | 1821      | 5000                          | 6000                            | 400 000                                                     |

## RIPPLE CURRENT AND USEFUL LIFE



Fig. 10 - Multiplier of useful life as a function of ambient temperature and ripple current load

Table 8

| <b>MULTIPLIER OF RIPPLE CURRENT (<math>I_R</math>) AS A FUNCTION OF FREQUENCY</b> |                                                         |                                        |                                                         |
|-----------------------------------------------------------------------------------|---------------------------------------------------------|----------------------------------------|---------------------------------------------------------|
| <b>FREQUENCY<br/>(Hz)</b>                                                         | <b><math>I_R</math> MULTIPLIER</b>                      |                                        |                                                         |
|                                                                                   | <b><math>U_R = 16 \text{ V to } 25 \text{ V}</math></b> | <b><math>U_R = 35 \text{ V}</math></b> | <b><math>U_R = 50 \text{ V TO } 63 \text{ V}</math></b> |
| 50                                                                                | 0.60                                                    | 0.45                                   | 0.40                                                    |
| 100                                                                               | 0.70                                                    | 0.65                                   | 0.60                                                    |
| 300                                                                               | 0.80                                                    | 0.80                                   | 0.75                                                    |
| 1000                                                                              | 0.85                                                    | 0.85                                   | 0.82                                                    |
| 3000                                                                              | 0.90                                                    | 0.90                                   | 0.90                                                    |
| 10 000                                                                            | 0.95                                                    | 0.95                                   | 0.95                                                    |
| 30 000                                                                            | 0.97                                                    | 0.97                                   | 0.97                                                    |
| 100 000                                                                           | 1.00                                                    | 1.00                                   | 1.00                                                    |

Table 9

| <b>TEST PROCEDURES AND REQUIREMENTS</b>     |                                          |                                                                                                                                                           |                                                                                                                                                                                    |
|---------------------------------------------|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>TEST</b>                                 |                                          | <b>PROCEDURE<br/>(quick reference)</b>                                                                                                                    | <b>REQUIREMENTS</b>                                                                                                                                                                |
| <b>NAME OF TEST</b>                         | <b>REFERENCE</b>                         |                                                                                                                                                           |                                                                                                                                                                                    |
| Mounting                                    | IEC 60384-18, subclause 4.3              | Shall be performed prior to tests mentioned below; reflow soldering; for maximum temperature load refer to chapter "Mounting"                             | $\Delta C/C: \pm 5 \%$<br>$\tan \delta \leq \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$                                                                                |
| Endurance                                   | IEC 60384-18/ CECC 32300, subclause 4.15 | $T_{\text{amb}} = 125 \text{ }^\circ\text{C}$ ; $U_R$ applied; for test duration see Table 7                                                              | $U_R \geq 16 \text{ V}$ ; $\Delta C/C: \pm 20 \%$<br>$\tan \delta \leq 2 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$                                            |
| Useful life                                 | CECC 30301, subclause 1.8.1              | $T_{\text{amb}} = 125 \text{ }^\circ\text{C}$ ; $U_R$ and $I_R$ applied; for test duration see Table 7                                                    | $\Delta C/C: \pm 30 \%$<br>$\tan \delta \leq 3 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$<br>no short or open circuit<br>total failure percentage: $\leq 1 \%$ |
| Shelf life<br>(storage at high temperature) | IEC 60384-18/ CECC 32300, subclause 4.17 | $T_{\text{amb}} = 125 \text{ }^\circ\text{C}$ ; no voltage applied; 1000 h<br>after test: $U_R$ to be applied for 30 min, 24 h to 48 h before measurement | For requirements see "Endurance test" above                                                                                                                                        |
| Reverse voltage                             | IEC 60384-18/ CECC 32300, subclause 4.16 | $T_{\text{amb}} = 125 \text{ }^\circ\text{C}$ :<br>125 h at $U = -0.5 \text{ V}$ , followed by 125 h at $U_R$                                             | $\Delta C/C: \pm 15 \%$<br>$\tan \delta \leq 1.5 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$                                                                    |



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